

Records of Odonata, Fish, and Birds from the Grafton Ponds Sinkhole Complex, York County, Virginia

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INTRODUCTION

Seasonal ponds, otherwise known also as vernal, autumnal or ephemeral pools, are an important wetland habitat for a variety of amphibians, reptiles, birds, and aquatic invertebrates (Baker et al., 1992; Kenk, 1949; LaClaire & Franz, 1990; Mahoney et al., 1990; Moler & Franz, 1987; Wiggins et al., 1980). Many species of amphibians and crustaceans (e.g., clam and fairy shrimps) are dependent on these temporary, fish-free environments for some or all of their life cycles.

A variety of unique pond habitats occur along the Atlantic Coastal Plain of North America, ranging from the Maritime Provinces in Canada south to Florida; these ponds are of various origin and known as kettle holes, sinkhole ponds, Delmarva bays, Carolina bays and cypress-gum ponds. They vary greatly in size and hydroperiod; some are temporary whereas others are permanent or nearly so. These habitats are perhaps best known for the many endemic plants that they support (e.g., Sorrie, 1994). A number of amphibians and reptiles, as well as several species of dragonflies and damselflies (Odonata) are also characteristic of these habitats (Carle, 1989; Carpenter, 1991; Gibbons & Semlitsch, 1991; May & Carle, 1996). Although they are fewer in number and less extensive in distribution than in many states to the north and south, the Coastal Plain ponds of Virginia remain relatively poorly studied from a zoological perspective.

The Grafton Ponds area of York County and the City of Newport News on the Lower Peninsula of Virginia (Figure 1) is regarded as the best remaining example of a Coastal Plain sinkhole pond complex in the state,

representing an exemplary occurrence of this rare natural community type (Clampitt, 1992; Clark, 1998; Rawinski, 1997b; Sankey & Schwenneker, 1993). This complex consists of more than 100 vernal ponds ranging in size from about 10 m to more than 100 m in diameter, and in shape from nearly circular to elliptical. Some of the ponds are believed to be several hundred thousand years old (Clark, 1998). The area in which they occur is underlain by marine silts and sands of the Chuckatuck Formation, which in turn are underlain by carbonate-rich sediments of the Yorktown Formation (Johnson, 1972; Mixon et al., 1989).

The Grafton Ponds sinkhole complex lies within a rapidly expanding urban area; some ponds have been destroyed in the past by commercial and residential development. Many of the ponds in York County are located on property owned and managed by the Waterworks Department of the City of Newport News, thus potentially affording some or all of them protection from adverse impacts. However, the area has a history of logging and conversion to pine plantations. In January of 1995, a 151 ha portion at the northern end of the city property was formally dedicated as a state Natural Area Preserve (Clark, 1998); this designation is intended to protect the area in perpetuity.

The present inventory was part of a multidisciplinary study conducted for the U.S. Environmental Protection Agency by the Virginia Department of Conservation and Recreation, Division of Natural Heritage (DCR-DNH) to prepare an ecological community classification of the sinkhole pond complex, conduct baseline zoological surveys, and prepare a natural resource management plan for the Natural Area Preserve. The results of the community classification and the management plan can be found in the reports by Rawinski (1997b) and Clark (1998), respectively. This paper presents the results of a portion of the zoological inventory.

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Previous zoological surveys of the Grafton Ponds area include a preliminary report on the avifauna (Sankey & Schwenneker, 1993) and observations of waterfowl use of the ponds (Rawinski, 1997a,b). Scattered records of Odonata (dragonflies and damselflies) and fish from the Lower Peninsula, although none known to have been obtained specifically within the Grafton Ponds area, are included in the works of Carle (1982), Davis (1938), and Jenkins & Burkhead (1993). Previous DCR-DNH collections of Odonata from the study area were apparently limited to five dragonfly species taken by Kurt A. Buhlmann on 16 April 1990 and several specimens of *Sympetrum vicinum* collected by K. E. Perry on 8 November 1988.

The primary purpose of the zoological inventory was to obtain baseline data on the use of specific ponds in the Grafton Ponds sinkhole complex by amphibians, reptiles, fish, and Odonata, with a particular emphasis on endangered, threatened, and rare species. Other study objectives were to evaluate the survey data for any obvious patterns of distribution and to identify the most significant ponds for these taxa. The results of the fish and Odonata surveys, as well as incidental observations on birds, are included in this paper.

The Odonata the best known group of aquatic insects in Virginia; the distribution and status of most other aquatic invertebrate groups (except freshwater mussels) in the state is poorly known by comparison. Carle (1979, 1982, 1991) and Roble (1994) have reviewed the status of the various dragonflies and damselflies in the state. DCR-DNH has conducted extensive surveys for Odonata in Virginia during the past decade. These surveys have demonstrated that numerous species that were thought to be rare or uncommon in the state only a decade ago are in fact more widely distributed, whereas other species have been confirmed to be quite rare and local (e.g., Roble et al., 1997; Stevenson et al., 1996). Recent surveys in Caroline County revealed a good correlation between the presence of rare and uncommon species of Odonata and the existence of exemplary Coastal Plain ponds (Roble & Hobson, 1996).

STUDY AREA AND METHODS

Study ponds were selected after conducting extensive reconnaissance visits with DCR-DNH vegetation community ecologists during the spring of 1995 to most of the ponds in the Grafton Ponds area. The 19 ponds targeted for intensive inventory during that year were chosen primarily for their potential to support breeding amphibian populations. This proved to be a "dry" year (i.e., below average precipitation; Rawinski, 1997b) and most of the ponds dried up prematurely in spring or early summer, somewhat hindering the zoological surveys.

Many pond basins were already dry or nearly so upon their first visit of that year. During 1996, all but two of these 19 ponds were resampled. During this "wet" year (above average precipitation), zoological surveys were expanded to include 31 other ponds in the study area in an effort to locate additional breeding sites of rare amphibian species, particularly the Mabee's salamander (*Ambystoma mabeei*). Many ponds retained water during that entire year (Rawinski, 1997b). In 1997, a limited number of visits were made to the most significant ponds identified during the first two years of the study. Most ponds dried up in July or August during 1997, and all were dry by the mid-September. Two brief visits were made to the study area in the spring of 1998, when all three ponds sampled were filled to capacity. Field work for this study was initiated in early April of 1995 and completed in mid-April of 1998. Stevenson made most of the observations through April 1996, whereas nearly all subsequent observations were obtained by Roble.

Adult Odonata were captured with standard insect nets or identified in flight. Limited sampling of larvae was also conducted. We surveyed for Odonata at 34 study ponds (including 20 on the Natural Area Preserve) and maintained records of all species that were encountered during each pond visit, as well as other species noted in the Grafton Ponds area but not found in association with a specific pond. In addition to the sinkhole ponds, we surveyed McCalley Run, a second order tributary of Beaverdam Creek, briefly on several occasions for the presence of adult Odonata. This area is located along the northwestern boundary of the Natural Area Preserve (Figure 1). We also examined the few specimens that were collected in the Grafton Ponds area during 1988-90 by DCR-DNH biologists to determine if any species were taken in addition to those documented during the present study (none were different). Identifications of adult Odonata were made using the descriptions, illustrations, and keys in Carpenter (1991), Dunkle (1989, 1990), Needham & Westfall (1955), and Westfall & May (1996). Representative voucher specimens of adult and larval Odonata were collected for positive identification and documentation of the Grafton Ponds fauna. Most of these specimens will be deposited in the recent invertebrate collection of the Virginia Museum of Natural History; a few will also be donated to the National Museum of Natural History (Smithsonian Institution). The common names of Odonata used in this report follow those recently adopted by the Dragonfly Society of the Americas (1996).

We surveyed for fish on at least one occasion at 50 ponds (including 26 on the Natural Area Preserve) using dip nets (primarily), seines, funnel traps, and minnow traps. Many of the bird species that we observed or heard incidental to the pond surveys were noted, but formal censuses were not conducted during this study. Further-

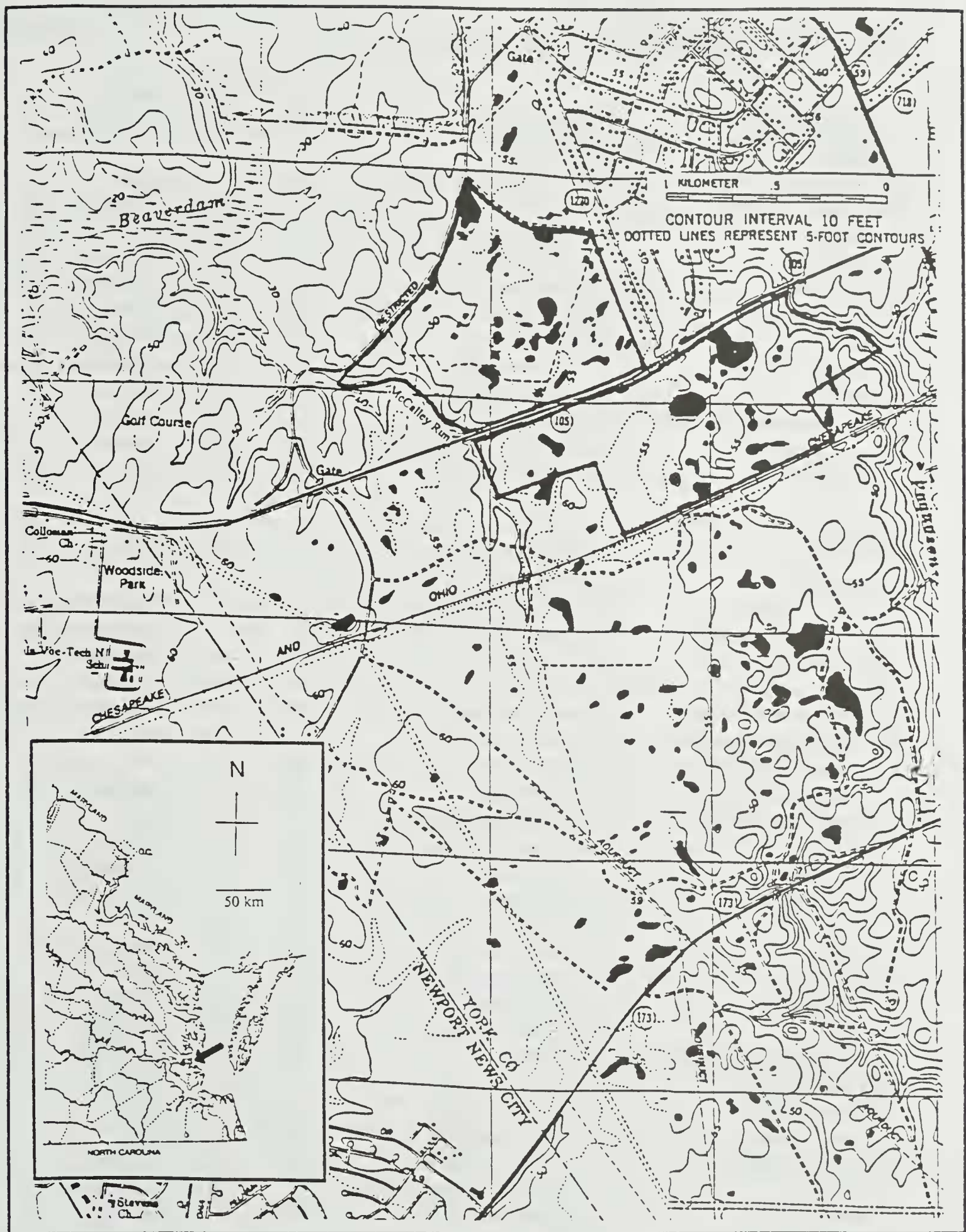


Fig. 1. General location of the Grafton Ponds area. The solid line indicates the boundary of the Natural Area Preserve. Ponds are depicted as darkened areas.

Table 1. Odonata documented in the Grafton Ponds area, 1995-98.

Scientific Name	Common Name	# of ponds	% of ponds	Relative abundance
Zygoptera	Damselflies			
<i>Calopteryx maculata</i> ^a	Ebony Jewelwing	(1)	-	Common
<i>Enallagma aspersum</i>	Azure Bluet	3	8.8	Uncommon
<i>E. civile</i>	Familiar Bluet	2	5.9	Rare
<i>E. geminatum</i>	Skimming Bluet	2	5.9	Uncommon
<i>E. signatum</i>	Orange Bluet	3	8.8	Uncommon
<i>Ischnura hastata</i>	Citrine Forktail	11	32.4	Common
<i>I. posita</i>	Fragile Forktail	20	58.8	Abundant
<i>I. prognata</i>	Furtive Forktail	8	23.5	Uncommon
<i>I. ramburii</i>	Rambur's Forktail	2	5.9	Rare
<i>Lestes disjunctus australis</i>	Common Spreadwing	18	52.9	Common
<i>L. rectangularis</i>	Slender Spreadwing	16	47.0	Common
<i>Telebasis byersi</i>	Duckweed Firetail	3	8.8	Rare
Anisoptera	Dragonflies			
<i>Anax junius</i>	Common Green Darner	17	50.0	Common
<i>A. longipes</i>	Comet Darner	1	2.9	Rare
<i>Celithemis eponina</i>	Halloween Pennant	4	11.8	Uncommon
<i>Cordulegaster maculata</i> ^a	Twin-spotted Spiketail	(1)	-	Uncommon
<i>Epiaeschna heros</i>	Swamp Darner	18	52.9	Common
<i>Epithea cynosura</i>	Common Baskettail	7	20.6	Uncommon
<i>Erythemis simplicicollis</i>	Eastern Pondhawk	15	44.1	Abundant
<i>Erythrodiplax minuscule</i>	Little Blue Dragonlet	1	2.9	Rare
<i>Gomphaeschna furcillata</i> ^b	Harlequin Darner	0	0.0	Rare
<i>Gomphus lividus</i> ^a	Ashy Clubtail	(2)	-	Common
<i>Libellula auripennis</i>	Golden-winged Skimmer	1	2.9	Rare
<i>L. axilena</i>	Bar-winged Skimmer	16	47.0	Common
<i>L. deplanata</i>	Blue Corporal	3	8.8	Uncommon
<i>L. incesta</i>	Slaty Skimmer	2	5.9	Uncommon
<i>L. luctuosa</i> ^b	Widow Skimmer	0	0.0	Rare
<i>L. lydia</i>	Common Whitetail	11	32.4	Common
<i>L. pulchella</i>	Twelve-spotted Skimmer	1	2.9	Rare
<i>L. semifasciata</i>	Painted Skimmer	12	35.3	Common
<i>L. vibrans</i>	Great Blue Skimmer	7	20.6	Common
<i>Pachydiplax longipennis</i>	Blue Dasher	17	50.0	Abundant
<i>Pantala flavescens</i>	Wandering Glider	1	2.9	Rare
<i>P. hymenaea</i>	Spot-winged Glider	1	2.9	Rare
<i>Perithemis tenera</i>	Eastern Amberwing	2	5.9	Rare
<i>Sympetrum ambiguum</i>	Blue-faced Meadowhawk	9	26.5	Uncommon
<i>S. vicinum</i>	Yellow-legged Meadowhawk	1	2.9	Uncommon
<i>Tramea carolina</i>	Carolina Saddlebags	8	23.5	Common
<i>T. lacerata</i>	Black Saddlebags	2	5.9	Rare

^aStream-breeding species that occur primarily along McCalley Run (relative abundance estimate pertains to this population).

^bRecorded once in the study area, but away from ponds.

more, we did not make a conscientious effort to record all of our bird sightings.

RESULTS

Odonata

A total of 39 species of Odonata (12 damselflies and 27 dragonflies) was recorded in the study area (Table 1). Most of these species are common and widespread in Virginia; five others are uncommon in the state and have been placed on the DCR-DNH Animal Watchlist, whereas two are monitored as state rare species. Three of the 39 species breed in lotic environments, typically small streams, and were recorded along McCalley Run, as well as 1-2 ponds each (usually single individuals). They are the ebony jewelwing (*Calopteryx maculata*), twin-spotted spiketail (*Cordulegaster maculata*), and ashy clubtail (*Gomphus lividus*). Two other species, the harlequin darter (*Gomphaeschna furcillata*) and the widow skimmer (*Libellula luctuosa*), were both recorded in the study area only once (the former may have been seen on two other dates), but not in association with a particular study pond. The harlequin darter is relatively uncommon in Virginia and typically breeds in boggy ponds and swamps. Eleven species were recorded at 10 or more of the 34 Odonata study ponds, whereas 17 (47%) of the non-stream species (i.e., lentic breeders) were documented at only 1-3 ponds (Table 1).

Thirty-two of the 39 (82%) species recorded during the entire study, including 11 of 12 (92%) damselflies, were found by the end of the first field season. A total figure in the range of 45-50 species of Odonata appears likely for the Grafton Ponds area. Species recorded from southeastern Virginia (Carle, 1982; Davis, 1938; Matta, 1978; Roble et al., 1997) that potentially inhabit some of the ponds, but which were not documented during this study, include the swamp spreadwing (*Lestes vigilax*), elegant spreadwing (*Lestes inaequalis*), lancet clubtail (*Gomphus exilis*), unicorn clubtail (*Arigomphus villosipes*), shadow darter (*Aeshna umbrosa*), spangled skimmer (*Libellula cyanea*), and several species of pennants (genus *Celithemis*). Two of these species (*G. exilis* and *A. umbrosa*) may have been seen once or twice each during this study, but our observations were too brief or distant to allow for positive identifications. The springtime darter (*Basiaeschna janata*), a stream-breeding species, may inhabit McCalley Run, but it was not recorded during our surveys. Relative to the entire Odonata fauna of Virginia, the fauna that inhabits the Grafton Ponds sinkhole complex is not particularly diverse, containing less than 25% of the state's species (Table 2). The small size and seasonal nature of most

Table 2. Species diversity of Odonata at Grafton Ponds as compared to the Odonata fauna of Virginia.

FAMILY	GRAFTON	VIRGINIA	PERCENT
Calopterygidae	1	7	14.3
Lestidae	2	10	20.0
Coenagrionidae	9	37	24.3
Total Zygoptera	12	54	22.2
Petaluridae	0	1	0.0
Aeshnidae	4	16	25.0
Gomphidae	1	39 ^a	2.6
Cordulegastridae	1	5	20.0
Corduliidae	1	19	5.3
Macromiidae	0	5	0.0
Libellulidae	20	43 ^b	46.5
Total Anisoptera	27	128	21.1
Total Odonata	39	182	21.4

^aExcludes one reported but unconfirmed species

^bExcludes one accidental and one unconfirmed species

ponds probably accounts to a large degree for the relatively low species diversity.

No evidence of Odonata was obtained at 10 of the 34 (29%) study ponds, whereas up to 30 species were recorded at the other ponds (Figure 2). More than a dozen species were present at only six ponds. More intensive sampling of all ponds probably would have increased their individual species totals. Several of the dragonflies that we recorded in the Grafton Ponds area may not breed at any of the seasonal ponds, but rather were possibly strays from nearby, permanent bodies of water (e.g., *Libellula incesta* and *L. luctuosa*). A few other species (e.g., *Pantala flavescens*, *Tramea lacerata*, and possibly *Libellula pulchella*) are known or suspected migrants that disperse widely in late summer and fall (Dunkle, 1989; May 1992).

Adult Odonata were recorded in the Grafton Ponds area between 30 March and 18 December. Many species were found on only a few surveys, whereas others were recorded on numerous visits (Table 3). The yellow-legged meadowhawk (*Sympetrum vicinum*) was moderately common on 18 December 1996, when approximately 25 adults, including two mating pairs, were observed at three of the seven ponds surveyed on that date. Needham & Westfall (1955) listed its known flight period as 2 June to 13 December, whereas Carle (1982) gave 28 May to 13 December, with the latest recorded date for Virginia being 22 November. Based on our review of additional literature, the Grafton record appears

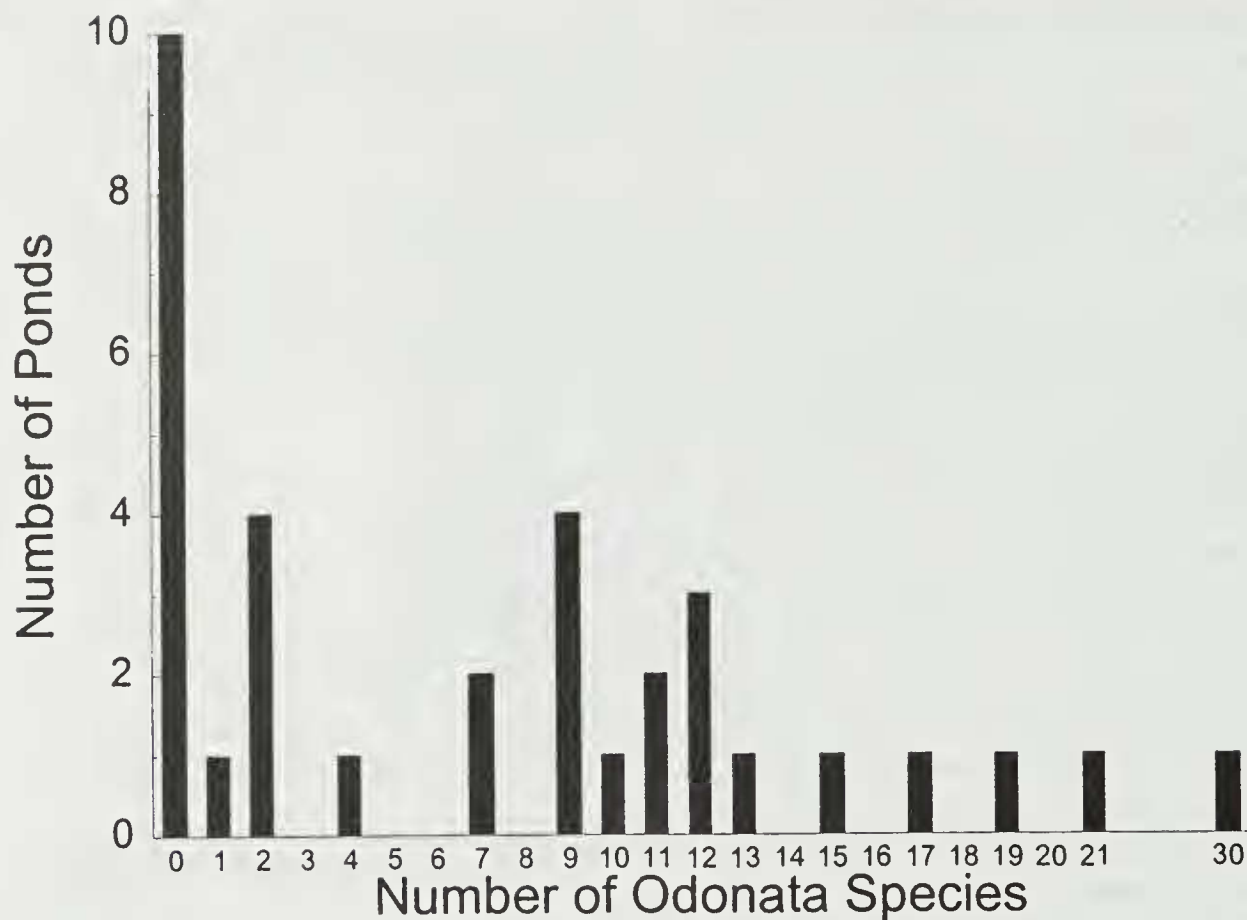


Fig. 2. Documented number of Odonata species per study pond.

to establish a new late date for this species. Despite relatively mild weather during the latter half of December 1996, adult Odonata were not observed during pond surveys conducted on 3 January 1997.

The most notable species of Odonata recorded at Grafton Ponds were the duckweed firetail (*Telebasis byersi*), comet darner (*Anax longipes*), and furtive forktail (*Ischnura prognata*). Davis (1938) did not record any of these species from the Lower Peninsula, although she subsequently collected a single male of the latter on 25 May 1938 in Williamsburg (Roble, 1994). Only one other recent record of this species (Sussex County) was known from Virginia prior to the present study (Roble, 1994); it is generally scarce throughout its range in the southeastern United States (Dunkle, 1990). Carle (1979) knew of only two Virginia localities for *A. longipes*, a large, very distinctive dragonfly (males have bright red abdomens), and considered it to be rare in the state. His subsequent compilation of dragonfly records for Virginia (Carle, 1982) added a third locality to his total, the nearest to the Grafton Ponds study area being in Charles City County. Roble & Hobson (1996) reported three additional sites for this species in the state. Although *A. longipes* is not globally rare, this species is considered rare to uncommon in virtually all of the states throughout its range (e.g., Carle, 1989; Carpenter, 1991).

The duckweed firetail, the males of which have scarlet red abdomens, is a small southern damselfly that was known only as far north as Merchants Millpond in Gates

County, North Carolina (Westfall, 1957) prior to its discovery in the Grafton Ponds area during 1995. It was subsequently discovered at a second site (Caroline County) farther north in the Coastal Plain of Virginia during that same year (Roble & Stevenson, 1996). More recently, the third Virginia locality for *T. byersi* was discovered by Roble, who found this species on 2 July 1998 in a cypress swamp along the Nottoway River within the Chub Sandhill Natural Area Preserve in Sussex County. Dunkle (1990) reported that *T. byersi* is found in semi-shaded lentic wetlands (e.g., swamps) containing abundant mats of floating vegetation such as duckweed (Lemnaceae); this type of habitat is rare in the study area. The duckweed firetail was first documented at Grafton Ponds (and Virginia) on 27 June 1995, when we captured a single male. It was not recorded in the study area again until another lone male was observed very briefly at a second pond on 2 July 1996. During the summer of 1996, Carolina mosquito-fern (*Azolla caroliniana*) nearly covered the surface of one study pond, but *T. byersi* was not found at this site. Evidence of breeding by this damselfly at Grafton Ponds was not obtained until 16 July 1997, when a dozen adults, including six males and three mated pairs, were discovered amongst sedges in shallow water at a third pond. Three adult males of *A. longipes* were also present at this pond during the same visit. This pond had been surveyed on numerous previous occasions without any sign of either of these species. Water levels at this pond dropped significantly by 5 September 1997,

when it was reduced to a shallow, remnant pool; the pond basin was completely dry two weeks later. Consequently, it is unlikely that either species successfully reproduced in the pond that year. Although *A. longipes* is a strong flier and probably capable of considerable dispersal movements, the presence of multiple individuals at this pond suggests that it may serve as a breeding site. However, a conclusive determination as to whether or not this pond functions as a regular (and successful) breeding site for either or both of these species will require additional field surveys.

The furtive forktail was known from only two sites (one was historic as noted above) in Virginia prior to the initiation of this study (Roble, 1994). However, we recorded this species at eight of the study ponds; several adults were also found along a Waterworks Department service road well removed from these ponds, suggesting the likelihood of an additional breeding site. A male that was captured on 16 April 1998 represents a new early flight date for Virginia, eclipsing the 22 April record reported by Roble et al. (1997). Our latest record (17 August) for *I. prognata* was of a teneral female. This formerly elusive species has been found at approximately a dozen other sites (mostly cypress-gum swamps) in the state during the past three years, indicating that it had been undersurveyed in the past (Roble et al., 1997; Stevenson et al., 1995). Unlike virtually all other species of Odonata that we recorded during this study, *I. prognata* prefers heavily shaded (rather than sunny) ponds and swamps.

Roble observed several instances of predation on adult Odonata that are worthy of brief mention. A fishing spider (*Dolomedes triton*) was found feeding on a female *Lestes rectangularis* on 21 June 1996 and a Great Crested Flycatcher (*Myiarchus crinitus*) was observed capturing adult dragonflies (most were probably *Libellula axilena*) at another large pond on 2 July 1996. Finally, a mature male *Ischnura posita* preyed on a teneral female *I. hastata*.

Fish

Considering the seasonal nature of all ponds in the Grafton Ponds sinkhole complex and the fact that each lacks an inlet or outlet, we assumed that fish were absent from the study area (exclusive of McCalley Run). Virtually every species of freshwater fish that inhabits Virginia requires water year-round for survival (Jenkins & Burkhead, 1993). Therefore, as expected, fish were not recorded during any of the pond surveys conducted in 1995 and 1996. However, on 5 September 1997, Roble discovered at least 20 eastern mudminnows (*Umbra pygmaea*) in a vestigial pool near the center of the nearly

dry basin of one of the largest ponds in the sinkhole complex. Several dozen southern leopard frog (*Rana sphenoccephala*) tadpoles, as well as hundreds of dragonfly larvae, were also present in the pool. The entire pond was completely dry when it was revisited two weeks later and there was no visible evidence of any fish, tadpoles or dragonfly larvae within the site of the former pool. This pond periodically goes dry, although it is usually one of the last ponds in the sinkhole complex to do so. We also recorded mudminnows on 30 May 1996 in a shallow (≤ 30 cm), marshy area within a powerline right-of-way approximately 5 km WNW of this pond (north of the Newport News City Reservoir) just across the Newport News city line. Jenkins & Burkhead (1993) plotted a record for *U. pygmaea* in this vicinity.

Additional surveys for fish at several of the larger, deeper and less ephemeral ponds may also reveal the presence of *U. pygmaea*. Although Jenkins & Burkhead (1993) reported this species from many locations in southeastern Virginia, including two sites on the Lower Peninsula, the Grafton Ponds record is the first documentation for York County. These authors report that *U. pygmaea* uses its gas bladder as a lung to survive in poorly oxygenated water (e.g., as ponds shrink in size during summer and become warm and stagnant) and aestivates in mud during drought conditions. Neill (1951) noted that he found several fish species, including pirate perch (*Aphredoderus sayanus*) and tadpole madtom (*Noturus gyrinus*), in crayfish burrows in Georgia when flatwoods cypress ponds were dry. It seems possible that *U. pygmaea* might be able to survive drought in this manner also. However, no crayfish burrows were evident in the immediate vicinity of the dry vestigial pool site during the survey conducted on 19 September 1997.

Birds

We recorded at least 28 species of birds in the Grafton Ponds area (Table 4) that were not included in the preliminary list of 40 species (reported as 41) prepared by Sankey & Schwenneker (1993). Their status designations of "resident" for the Brown Creeper (*Certhia americana*) and Yellow-rumped Warbler (*Dendroica coronata*) and "summer" for the Blackpoll Warbler (*Dendroica striata*) are questionable. The latter is present in the Grafton Ponds area only during migration and the other two species are absent during the summer months. Sankey & Schwenneker (1993) also listed the Mallard (*Anas platyrhynchos*) as a migrant, but our observations indicate that at least one pair attempted to nest in the Grafton Ponds area. Rawinski (1997a, b) added the American Black Duck (*Anas rubripes*) to the known avifauna of the Grafton Ponds area based on a single observation. Avian

predators of fish and amphibians that we observed at the study ponds include the Great Blue Heron (*Ardea herodias*) and Green Heron (*Butorides striatus*).

DISCUSSION AND CONCLUSIONS

The first step in conserving biological diversity is to conduct inventories of the flora and fauna present in an area. A baseline knowledge of the biota is needed before management strategies can be developed. During our three-year inventory of the fauna of the Grafton Ponds sinkhole complex, we recorded one fish, 27 dragonfly and 12 damselfly species. Faunal inventories can never be considered absolutely complete in terms of their ability to detect all of the species present in an area. Gibbons et al. (1997) stress the need for long-term sampling to thoroughly document the herpetofauna of a particular area, noting that cryptic species such as some snakes may take years or even decades of effort to discover, especially if the survey area is large.

Few species accumulation curves are available to evaluate the efficiency of odonatological inventories. We are aware of only two published graphs for this group of insects. These were prepared by Louton et al. (1996) for a tropical lowland forest site in Peru and by Roble & Hobson (1996) for the Fort A. P. Hill Military Reservation in the Coastal Plain portion of Caroline County, Virginia. The species accumulation curve derived from our surveys for Odonata at Grafton Ponds indicates that the rate of discovery of new species was beginning to decline in the latter portion of the study, although additional species were still very likely to be recorded from the area (Figure 3). Our previous estimate of 45-50 total species for the area seems reasonable; only 39 species were verified during the present study. The 34 study ponds were sampled to varying degrees, with some visited only once and others surveyed numerous times. Furthermore, many additional, though mostly smaller, shallower, or more ephemeral ponds, were not sampled at all.

Davis (1938) recorded a total of 44 species of Odonata from the Lower Peninsula of Virginia, 30 of which were found during the present study (assuming that her records of the sweetflag spreadwing, *Lestes forcipatus*, are referable to *L. disjunctus australis*; see Walker, 1952). Of the remaining 14 species, three are stream dwellers, one inhabits seepages and two others are typically associated with coastal marshes (as is Needham's skimmer, *Libellula needhami*, which was not described until 1943 and probably comprises most or all of Davis' records of *L. auripennis*) and thus were not expected to occur at Grafton Ponds. The origin of an unlabelled specimen of the four-spotted skimmer, *Libellula quadrimaculata*, in the entomological collection at the College of William

and Mary, which Davis (1938) presumed to have been collected in Williamsburg, is uncertain. There are no other records of this Holarctic species from Virginia (Carle, 1982), and thus we believe that it should not be regarded as a verified member of the state's fauna. Suitable breeding habitat (bogs) does not exist in the Williamsburg area; however, this species is migratory, and it is remotely possible that an adult could have wandered this far south (Carle, 1982).

The composition of the Odonata fauna of the Grafton Ponds area is varied, and includes some species with predominantly northern (boreal) or southern (austral) affinities, as well as numerous species that have broad distributions in eastern North America. The Odonata fauna also includes several transcontinental species as well as one nearly cosmopolitan species (*Pantala flavescens*). Excluding very widespread species, the general trend is biased toward austral rather than boreal species. Examples of southern species include the duckweed firetail, furtive forktail, little blue dragonlet, and great blue skimmer; northern species include the azure bluet.

The diversity (i.e., species richness) of the Odonata fauna of the Grafton Ponds area is not particularly high relative to other areas in the state or region, nor is the composition of this fauna unusual. However, few published studies are available from specific sites in Virginia or the region that allow for direct comparisons. The pond-breeding fauna of the Grafton Ponds area is compared with the faunas of several other sites in Virginia and the eastern United States in Table 5. We readily acknowledge that a number of factors, including survey methods, size of study area, length of study, and type of habitat were not consistent between the various studies included in these comparisons, and can greatly influence the documented faunal composition of each site.

Orr (1996) found all but two (*Ischnura prognata* and *Telebasis byersi*) of the Grafton Ponds species, including all three stream-breeders that we recorded along McCalley Run during the present study, at the Patuxent Wildlife Research Center site in eastern Maryland (highest percent overlap); he also documented many other species at this site (hence a lower percent similarity value). Only three of the Grafton species (*I. prognata*, *Libellula pulchella*, and *Pantala hymenaea*) were not documented by Roble & Hobson (1996) at the Fort A. P. Hill Military Reservation in Caroline County, Virginia; most of their survey sites were beaver-impounded, naturally acidic Coastal Plain ponds that are more permanent and heavily vegetated than the Grafton ponds. Both of the state rare Odonata species present at Grafton Ponds (i.e., *Anax longipes* and *Telebasis byersi*) occur on Fort A.P. Hill, as do numerous other rare and uncommon

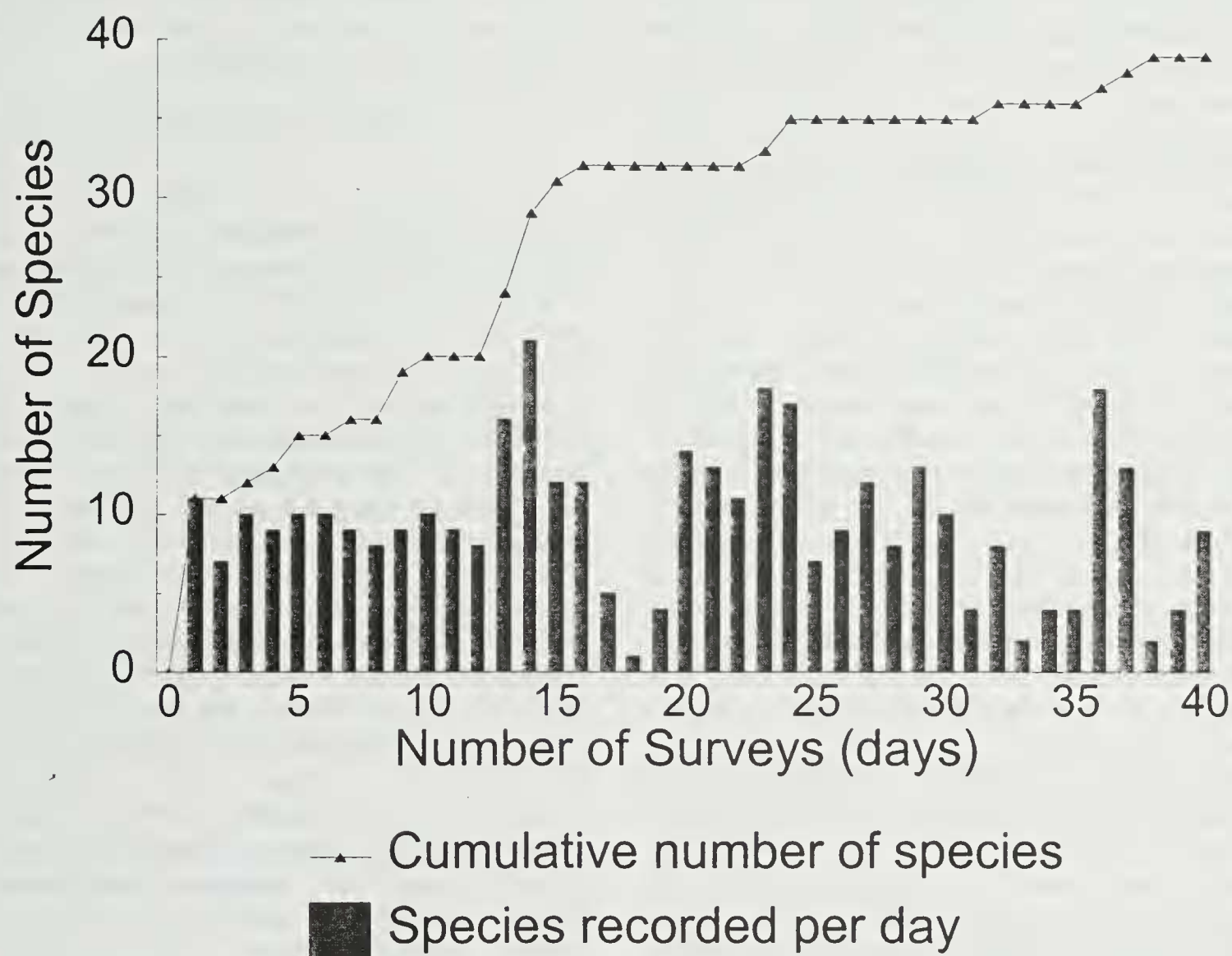


Fig. 3. Species accumulation curve for Odonata at Grafton Ponds.

species that were not found during the present study. The areas surveyed by Orr (1996) and Roble & Hobson (1996) were larger than the Grafton Ponds study area and included a greater variety of lentic habitats, somewhat complicating these comparisons. However, Roble & Hobson (1996: 38-39) also provide data on their six most diverse Odonata survey sites at the Fort A. P. Hill Military Reservation. The number of pond-breeding species recorded at these sites ranged from 21 to 33, including 1-5 state rare species and 5-11 Watchlist species per pond. By comparison, only two study ponds in the Grafton Ponds area supported at least 20 species of Odonata. Two state rare and one Watchlist species were recorded at the most species-rich pond, whereas two

Watchlist species were present at the other pond. Despite their great distance from Virginia, most of the study sites from the other states that are included in Table 5 share at least two-thirds of the Odonata species present at the Grafton Ponds.

Seasonal ponds are unpredictable in their occurrence in time and space and may be regarded as ecological islands of habitat for species that are dependent on them for some portion of their life cycle (Ebert & Balko, 1984; Holland & Jain, 1981). Hydroperiod data obtained by Rawinski (1997b) for 35 study ponds within the Grafton Ponds sinkhole complex clearly conform to this unpredictable pattern. Variation in annual hydroperiod duration dramatically affects the reproductive success of

most species that inhabit the ponds, such that entire cohorts may be lost to premature drying. While most members of the local amphibian fauna of the Grafton Ponds are adapted to persist through occasional drought years, many of the dragonflies and damselflies are not. The Grafton Ponds population of larval Odonata may be almost entirely lost in some years, necessitating recolonization from other sites. Approximately 1.5 h of extensive dipnetting on 16 April 1998 at the last pond to dry the previous fall (= the pond with 30 documented species of adult Odonata) failed to result in the capture of a single Odonata nymph; other species of aquatic insects were generally scarce in the dipnet samples, whereas isopods and juvenile crayfish were common. With the exception of members of the genus *Lestes*, which often lay their eggs above the water line and exhibit embryonic diapause (primarily for overwinter survival; Westfall & May, 1996), most of the damselflies are not adapted to tolerate drought conditions. They must recolonize the area from other habitats where their larvae have survived. The larvae of some of the dragonfly species documented during this inventory may have behavioral or physiological adaptations to survive drought, whereas others probably must recolonize the area regularly.

As noted earlier, the zoological study ponds were divided almost equally between those which lie within as opposed to outside of the Natural Area Preserve. As Rawinski (1997b) demonstrated for the flora, the faunal composition of some of the most southerly ponds may have been altered by clearing of the forest canopy. For example, several Odonata, most species of which prefer sunny as opposed to shaded habitats, and certain amphibian species may be more common at some of these ponds than they were prior to logging of the immediate vicinity of the pond. By comparison, the ponds within the Natural Area Preserve are still largely forested. Few of the study ponds supported a diverse Odonata fauna; small to medium-sized ponds with mostly closed canopies generally had five or fewer species recorded. One pond led all others by a significant margin with 30 confirmed species (of 36 total pond-breeders), although some of these may have merely been non-breeding adult visitors. Two other ponds also harbored a good diversity of Odonata (21 and 19 species, respectively). The latter pond lies within a powerline right-of-way (hence it is open canopied) and is heavily vegetated; two Watchlist species (*Erythrodiplax minuscula* and *Libellula auripennis*) that were not found at any of the other study ponds were recorded at this pond on several occasions (both species were also observed at another site within the right-of-way).

The biological value of the Grafton Ponds complex is perhaps best viewed from the perspective of their ever-increasing importance as habitat for a moderately diverse

assemblage of plants and animals in a rapidly urbanizing landscape. Judgements about the value of individual ponds may not be appropriate. Protection of the full suite of ponds, including those outside of the Natural Area Preserve, is highly desirable. Collectively, the Grafton Ponds sinkhole complex constitutes one of Virginia's most significant natural communities.

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Table 3. Seasonal distribution of Odonata at the Grafton Ponds sinkhole complex, York County, Virginia.

Month	Mar.	Apr.	May	June	July	August	Sept.	Oct.	Dec.	Early and Late Flight Dates
Species	Quarter ^a	4	3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2	3	* = Extreme date for Virginia ^b
<i>Calopteryx maculata</i> <i>Lestes disjunctus australis</i> <i>L. rectangularis</i>			x x x x x	x x x x x x x x	x x x x x x x x	x x x x x x x	x x x x	x x		24 May - 15 August 20 April - 11 October 16 May - 11 October
<i>Enallagma aspersum</i> <i>E. civile</i> <i>E. geminatum</i> <i>E. signatum</i>			x x x . x	x x x x x x	x x x x x x x x	x x x x x x x	x x x x			3 May - 5 September 3 May - 27 June 2 July - 5 September 24 May - 17 August
<i>Ischnura hastata</i> <i>I. posita</i> <i>I. prognata</i> <i>I. ramburii</i> <i>Telebasis byersi</i>	x x	x x x x	x x x x x x x x x x	x x x x x x x	x x x x x x x x x x x	x x x x x x x	x x x	x x		30 March* - 11 October 30 March* - 11 October 16 April* - 17 August 30 May - 15 August 27 June* - 16 July
<i>Anax junius</i> <i>A. longipes</i> <i>Epiaesclina lieros</i> <i>Gomphaeschna furcillata</i>	x	x x x x ? x	x x x x x x x x ?	x x x x x x	x x x x	x x x	x		x	30 March* - 18 December 16 July 16 April - 6 August 28 April
<i>Epithea cynosura</i> <i>Gomphus lividus</i> <i>Cordulegaster maculata</i>	x	x x x x x	x x x x x x							16 April - 24 May 30 March - 24 May 16 April - 10 May
<i>Celithemis eponina</i> <i>Erythemis simplicicollis</i> <i>Erythrodiplax minuscula</i>			x x x ? ?	x x x x x x x x	x x x x x	x x x x x	x x x x	x		7 June - 16 July 5 May - 19 September 21 June - 11 October
<i>Libellula auripennis</i> <i>L. axilena</i> <i>L. deplanata</i> <i>L. incesta</i>		x x x x	x x x x x	x x x x x x	x x x x x x x x	x x x x x x	x x			7 June - 27 June 15 May - 5 September 16 April - 17 May 2 July - 5 September
<i>L. luctuosa</i> <i>L. lydia</i> <i>L. pulchella</i> <i>L. semifasciata</i> <i>L. vibrans</i>		x x x x	x x x x x x x x x	x x x x x x x	x x x x x x x	x x	x x			28 June 16 April - 5 September 5 September 20 April - 27 June 24 May - 5 September
<i>Pachydiplax longipennis</i> <i>Pantala flavescens</i> <i>P. lymanaea</i> <i>Perithemis tenera</i>			x x x x x	x x x x x x x x x	x x x x x x x x x	x x x x x	x x			15 May - 5 September 5 September 26 July 24 May - 15 August
<i>Sympetrum ambiguum</i> <i>S. vicinum</i> <i>Tramea carolina</i> <i>T. lacerata</i>		x x x x	x x x x x x	x x x x x x x	x x x x x x	x x x x x x x	x x	x x x	x	27 June - 11 October 5 September - 18 December* 16 April* - 17 August 21 June - 16 July

^aQuarters of the month: 1st to 8th (1), 9th to 15th (2), 16th to 23rd (3), and 24th to the end of the month (4); no data for missing or underlined quarters.^bExceeds or equals early or late date reported by Carle (1982), Roble (1994) or Roble et al. (1997).

Table 4. Partial list of bird species recorded in the Grafton Ponds area during this study; these species were not included in the reports by Sankey & Schwenneker (1993) or Rawinski (1997a, b). Status codes are: R = resident; S = summer, potential breeder in this area; SC = summer, confirmed breeder; M = migrant; V = potential visitor at any time of year.

<u>Common Name</u>	<u>Scientific Name</u>	<u>Date(s)</u>	<u>Pond(s)</u>	<u>Status</u>
Great Blue Heron	<i>Ardea herodias</i>	13 March - 16 July (5 dates)	N1 (all dates), N7, N22, S16, R5	V
Green Heron	<i>Butorides striatus</i>	30 May - 16 July	N1, S1, S4	S
Black Vulture	<i>Coragyps atratus</i>	26 April - 16 July	N1, N8 ^a	V
Red-tailed Hawk	<i>Buteo jamaicensis</i>	16 July 1997 (juvenile)	N18	S
Spotted Sandpiper	<i>Actitis macularia</i>	20 April 1995	S1	M
American Woodcock	<i>Scolopax minor</i>	3 January 1997 ^b	R26	R
Yellow-billed Cuckoo	<i>Coccyzus americanus</i>	16 July 1996	N1	S
Great Horned Owl	<i>Bubo virginianus</i>	26 September 1996 (pair)	S1	R
Ruby-throated Hummingbird ^c	<i>Archilochus colubris</i>	16 April - 7 June	N1, N11	SC
Belted Kingfisher	<i>Ceryle alcyon</i>	16 April - 7 June	N1 ^d	V
Pileated Woodpecker	<i>Dryocopus pileatus</i>	10 May 1996 (pair)	McCalley Run	R
Great Crested Flycatcher	<i>Myiarchus crinitus</i>	16 April - 2 July	N1	S
American Crow	<i>Corvus brachyrhynchos</i>	16 April 1998	N1	R
Carolina Wren	<i>Thryothorus ludovicianus</i>	30 March 1998	McCalley Run	R
Blue-gray Gnatcatcher	<i>Poliophtila caerulea</i>	16 April 1998	N1, N11 (nest), N22, McCalley Run	SC
American Robin	<i>Turdus migratorius</i>	30 March - 16 April	N1, N11, N22	R
Yellow-throated Vireo	<i>Vireo flavifrons</i>	7 June 1997	N1	S
Northern Parula	<i>Parula americana</i>	16 April - 7 June	N22, McCalley Run	S
Black-and-white Warbler	<i>Mniotilta varia</i>	16 April - 21 June	N1, N11, S16, R26	S
Prothonotary Warbler	<i>Protonotaria citrea</i>	17 May 1996 (pair)	N1	S
Louisiana Waterthrush	<i>Seiurus motacilla</i>	30 March - 10 May	S1, McCalley Run	S
Yellow-breasted Chat	<i>Icteria virens</i>	21 June - 16 July	S16, R15	S
Summer Tanager	<i>Piranga rubra</i>	17 May - 16 July	N3, R20	S
Blue Grosbeak	<i>Guiraca caerulea</i>	7 June 1997	N1	S
Chipping Sparrow	<i>Spizella passerina</i>	16 April 1998	N1, N22	S
Red-winged Blackbird	<i>Agelaius phoeniceus</i>	30 March 1998	N1	R
Brown-headed Cowbird	<i>Molothrus ater</i>	30 March 1998	N1	R
American Goldfinch	<i>Carduelis tristis</i>	30 March - 5 September	N1, N7, N11, McCalley Run	R

^aAdult flushed from roost in hollow tree on 26 April 1995.

^bCourtship flights heard on this date.

^cFemale observed at nest by DCR-DNH biologists at Pond S1 on 1 May 1990.

^dAlso recorded at this pond by DCR-DNH biologists on 8 November 1988.

Table 5. Comparison of the Odonata fauna of Grafton Ponds, York County, Virginia, with other areas in Virginia and the eastern United States.

Reference	State	Locality/Habitat	Pond breeders	Shared species ^a	Overlap as % of Grafton fauna	Percent similarity ^b
Davis 1938	VA	Lower Peninsula (various lentic habitats)	35	27	75.0	61.4
Matta 1978	VA	Southeast corner (various lentic habitats)	46	30	83.3	57.7
Roble & Hobson 1996	VA	Fort A. P. Hill Military Reservation, Caroline County (Coastal Plain ponds)	59	33	91.7	53.2
S. M. Roble (unpublished data)	VA	Maple Flats, Augusta County (sinkhole pond complex)	49	27	75.0	46.6
S. M. Roble (unpublished data)	VA	Cat Ponds, Isle of Wight County (seasonal Coastal Plain ponds)	24	20	55.6	50.0
Donnelly 1961	VA/MD	Washington, D.C. area (various lentic habitats)	68	30	83.3	40.6
Orr 1996 + pers. comm. additions	MD	Patuxent Wildlife Research Center (various lentic habitats)	76	34	94.4	43.6
Soltesz 1991	NJ	Cape May County ^c				
		site #4	23	17	47.2	40.5
		site #25	22	20	55.6	52.6
Barber 1994	NJ	Cumberland County ^d				
		site #2	32	17	47.2	33.3
		site #14	28	23	63.9	56.1
Kondratieff & Pyott 1987	SC	Savannah River Plant	28 ^e	21	84.0	65.6
Carpenter 1991	MA	Cape Cod, Barnstable County (Coastal Plain ponds)	80	31	86.1	36.4
Vogt & McPherson 1986	IL	Union County (swamp)	34	25	69.4	55.6
Vogt et al. 1986	IL	Pope County (man-made fishless, woodland pond)	25	19	52.8	45.2

^a Species in common with Grafton Ponds fauna; based on 36 species of pond-breeding Odonata documented during the current study at the Grafton Ponds sinkhole complex, including 25 species of Anisoptera (dragonflies).

^b Percent similarity = Number of Shared Species / (Total Species from Grafton Ponds + Total Species at comparison site - Number of Shared Species)

^c Site 4 consisted of a buttonbush bog and adjacent wet savannah; site 25 was a wet savannah.

^d Site 2 was a semi-permanent, deep woodland vernal pond; site 14 consisted of two nearby woodland vernal ponds.

^e Only includes Anisoptera species that were recorded from ponds and Carolina bays (from Table 1 in reference).